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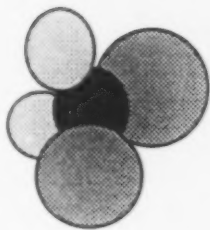
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ABSTRACT

This curriculum consists of a series of Learning Activity Packets (LAPs) on the chemistry involved in different aspects of modern society. It is intended for non-majors and introduces fundamental concepts by engaging students in hands-on learning activities. The LAPs are designed to make connections between chemistry and other fields of interest to the students, incorporate a variety of strategies to promote active learning and accommodate different learning styles, emphasize first-hand experiences in scientific inquiry, and provide an attractive introduction for further studies. Prominent features of the LAPs are discussed including LAP format, interactive lab exercises, first-hand experiences, modular approach, and writing to learn. Also discussed are the instructor's role and class testing results. Appendices include list of LAP titles, sample LAP schedule, and a summary of student evaluations. (JRH)

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Learning Chemistry in Laboratory Settings

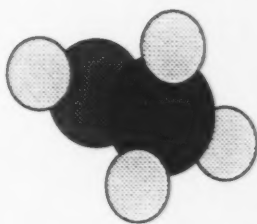
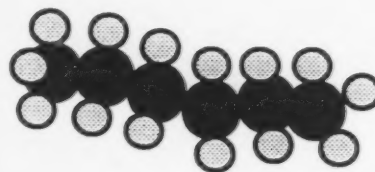
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A Hands-On Curriculum For Non-Science majors

*Laboratory Leadership
Development Grant
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Learning Chemistry In Laboratory Settings A Hands-On Curriculum For Non-Science Majors

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A Brief Description

This curriculum consists of a series of learning activity packets (LAPs) on the chemistry involved in different aspects of the modern society. I developed these LAPs with the help of faculty advisors whose specialties are other than chemistry. The unique emphasis of this curriculum is to introduce fundamental chemistry concepts by engaging students in hands-on learning activities. It is intended for the non-majors. I wish to provide students with a meaningful overview of chemistry and its multifarious applications. This is why I designed the LAPs to:

- ♦ make connections between chemistry and other fields of interest to the students;
- ♦ incorporate a variety of strategies to promote active learning, and accommodate different learning styles;
- ♦ emphasize first-hand experiences in scientific inquiry; and
- ♦ provide an attractive introduction for further studies.

A few *prominent features* of the LAPs are discussed in the following section. Since this LAP approach differs from most conventional practices, I will also discuss briefly the *instructor's role* in using this curriculum. First year *class testing results* are given in the concluding section of this report.

This curriculum reform project is currently being conducted at Spokane Community College (SCC), with the support of a 1994 Laboratory Leadership Development grant from the National Science Foundation, Division of Undergraduate Education (DUE-9452258). A preliminary version of this report was presented in the first annual *Teaching In The Community Colleges (TCC-L) On-Line Conference*, April 2-4, 1996. (The original report is still available for viewing on the Internet at: http://leahi.kcc.hawaii.edu/org/tcc_conf/wang.html)

Prominent Features

LAP Format

The format of the LAPs is a mix between traditional laboratory manual and textbook. Each LAP has a central theme or topic which unfolds through short paragraphs of explanations with interspersed laboratory and other hands-on activities. Students take the active part of learning by completing the LAPs in lab settings; each LAP will require about two hours class time. Main concepts are summarized in three or four *learning objectives* at the beginning of each LAP. A *further studies* section appears as take-home assignments at the end, and provides more breadth and depth to the discussions. Important terms and ideas are re-emphasized in two sections: *key terms review* and *LAP review questions*. Not all of the learning activities require laboratory space or equipment. For examples: lectures, student presentations, class demonstrations, or small group discussions can be conducted in a traditional classroom.

Interactive Lab Exercises

Many of the hands-on exercises are *interactive*. Traditional lab experiences point students' attention to getting "good results" by following prescribed procedures. Students conduct observations and data collection in lab, and go home to analyze results and draw conclusions. They tend to go through lab procedures passively without grasping related concepts. The exercises in these LAPs aim at training students to become more

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careful observers and critical thinkers *during* the exercise. They are relatively short, and most of them use small scale materials and equipment. In these exercises, students test or demonstrate new ideas *as they are being presented*. They analyze results immediately, and are asked to answer critical questions concerning an experiment *before* the experiment is over. For example, a discussion of oxidation-reduction reactions is directly followed by a lab exercise of tarnish removal from silverware by aluminum. As students observe the silver recovery process, they are balancing redox equations. They identify which reactant is being oxidized, and which is being reduced. I develop each concept by considering how it can be simply illustrated with a hands-on activity. And, vice versa, I link each hands-on exercise to one or more concepts by asking pertinent questions during the activity to lead the students on.

First-Hand Experiences

The LAPs include many activities in which students discover facts or derive ideas from first-hand learning. Most ideas or facts are presented traditionally through lectures, textbook reading or even demonstrations in a filmstrip or in class. All of these are *second-hand* learning experiences, because the learners are the *audience* and not the *players*. In these LAPs, *students are the players*; they are given opportunities to learn first-hand for themselves as much as appropriate. For example: students build molecular models to "discover" how ice has hexagonal holes in its structure. They search a periodic table to note trends of atomic mass. They perform a series of precipitation reactions and identify the most cost-effective way to remove silver from a silver-containing waste stream.

Modular Approach

The LAPs are organized into several topic modules; a module contains up to eleven LAPs. The topics include fundamental concepts (FC series), nutrition and food (NF series), the environment (EV series), nuclear (NU series), and medicine and health (MH series). The FC series introduce the chemistry needed in other modules. However, it is not necessary to complete all of the FC LAPs before starting another module. For example, if class interest is high, the instructor may choose to start the nuclear LAPs immediately after LAP FC.1 *Atoms & Molecules*. Appendix A provides a list of the LAPs, some of which are yet to be developed in the next year. Appendix B gives a sample LAP schedule for a 5-credit (quarter system) liberals chemistry course. The instructor's manual will provide correlation charts of all the LAPs to help instructors select and schedule appropriate LAPs.

I use this topical and modular approach because I believe motivations for learning come from seeing the relevance. I also believe that most people are eager to learn why and how things work, if they receive proper guidance. This approach reinforces important chemical principles from different perspectives. For example, the concept of molecular polarity and the like-dissolves-like rule appear in almost every module. Students learn this concept in different contexts of solutions, soap, vitamins, lipids, and drug absorption etc. Competency in a subject eventually builds up when one sees and understands it from all angles.

Writing to Learn

There are many benefits of using writing assignments in chemistry courses. These can enhance students' comprehension of concepts, improve communication between students and the instructor, and also serve as assessment instruments. I have used a variety of writing assignments in my own teaching, and have enjoyed seeing positive results. This is why I provide ample opportunities for students to write in these LAPs. These opportunities range from "Describe what you see in detail." and "Write a 50 to 100-word paragraph to explain ...", to one-page summary reports of lab, reading or field trip experiences. Many instructors think writing assignments are time consuming to grade and hard to evaluate. This has not been my experience. In principle, it helps if the instructor views writing assignments as a means to assess how students think, and not attempt to teach them how to write. Also, evaluation becomes easier with simple but specific guidelines and grading

criteria that can help students focus their writing. I am including in the instructor's manual many specific writing evaluation criteria I have used in past years.

Instructor's Role

This curriculum is student-centered. The materials are for use mostly during class time. The focus of a LAP session is on learning, not on teaching. During a session, the instructor is a leader in the sense of a *tour guide*, a *coach* and a *resource person*. As a *tour guide*, the instructor gives short presentations at different times during class to help students grasp major concepts. He or she is there to point out what these "tourists" or "first-time visitors" tend to miss, if left on their own. As a *coach*, the instructor supports the "players" in the learning teams by keeping them on task, demonstrating proper techniques, and monitoring the progress of each one. As a *resource person*, the instructor provides a comfortable learning environment with necessary resources (lab materials and equipment, reference books, display items, charts or figures, guest speakers, etc.) He or she is available when questions or problems arise. The above description does not mean, however, that the instructor no longer lectures in the traditional sense. Good lectures are still the most effective approach in some cases. The best approach is to adopt a teaching style somewhere between the two extremes of being solely a *transmitter of knowledge*, versus being a plain *facilitator*.

An instructor can use this curriculum in many ways. It can serve as the main text for a liberal arts chemistry course. Or, selected LAPs can cover the entire laboratory portion of the one year General-Organic-Biochemistry course for the nursing and allied health students. It also has great potential for use in a telecourse or distance learning setting, in which class meet only to complete LAP sections that require laboratory chemicals and equipment. Class testings are underway in these various settings. Furthermore, this curriculum can be adapted for large enrollment classes with limited laboratory facilities. In such cases, students could work in groups with the help of teaching assistants during class sessions. Some hands-on exercises could be performed as class demonstrations. Some others could be set up in the laboratory, and students would go in and do the exercises, a few groups at a time.

First Year Class Testing Results

Institutional Background

Spokane Community College (SCC) is a two-year college with extensive vocational programs and a high percentage of nontraditional students. Out of 5,500 Full-Time-Equivalents (FTE), about 2000 FTE take courses offered in the SCC Liberal Arts Division. Of these 2000, 50% are pursuing a vocational certificate or an associate in applied sciences (A.A.S.) degree. The other 50% are pursuing the associate of arts (A.A.) degree, which allows direct transfer to four-year institutions as Juniors. Most students have little or no high school science background. The majority of those who take science courses are pursuing careers in nursing and allied health sciences, and around 80% to 90% of these are female.

The chemistry offerings at SCC serve over 250 students per quarter. We offer a variety of first-year college chemistry courses, including: the advanced general chemistry series (Chem 141, 142, 143) for science and engineering majors, the health science chemistry series (Chem 161, 162, 163) for nursing and allied health majors, a liberal arts chemistry course (Chem 100) and a technical inorganic chemistry course (Chem 130) for vocational programs. All of these are five-credit courses, which meet seven hours per week: three 50-minute lecture sessions and two 110-minute laboratory sessions. The same instructor teaches both the lecture and laboratory sessions of a course. There are 25 students per lab section. Lecture size can be up to 75 or 100, by combining lab sections.

The New Chemistry Mini-Course Series

This curriculum reform project is actually the culmination of a gradual process. Many existing factors at SCC, such as student responses, class schedules, and lab facilities, favored a gradual shift from the traditional

lecture-lab format of teaching introductory chemistry to a student-centered, *laboratory learning* approach. With the support of the NSF grant, we were able to accelerate this shift into a full-turn, and introduce a series of new chemistry mini-courses. These are one to three variable-credit courses, under the general title of *Chemistry in Modern Society: Fundamental Concepts & Practical Applications*. The uniqueness of these courses is that lecture and lab hours are not separate; they merge into one in hands-on learning sessions of two hours each. Each mini-course requires around 16 hours class time per credit received. This is proportionally equivalent to the 77 contact-hours required for a traditional five-credit lab science course at SCC. The new courses include: (1) Chem 110: Fundamental Concepts mini-course, a variable one- to two-credit course; and (2) Chem 111,112,113: a series of topic-oriented mini-courses, each of variable one to three credits. None of these mini-courses requires prior chemistry exposure. Credits from these courses are directly transferable to four year institutions; they are equivalent of a liberal arts chemistry course.

The mini-course options encourage students to take chemistry without a full 5-credit commitment all at once. They also allow students to choose their own topics of interest. For example, vocational students in the dietary technician program are taking the *chemistry in nutrition and foods* mini-course; and those in the water resources program are electing the *environmental chemistry* mini-course. Liberal arts students, on the other hand, are taking two or more mini-courses to accumulate 5 credits of lab science, required for the Associates of Arts degree at SCC. Some students have also taken the mini-courses to prepare for traditional college science courses. A few working professionals found their way into these mini-courses for personal enrichment and continuing education.

Pilot classes from the past year have consistently been very encouraging. Students particularly enjoy the variety of hands-on learning opportunities; they also appreciate how "science lessons can be applied or observed in everyday life," and that the LAPs allow "easy access to a challenging subject." 82% indicated that they will take another mini-course in the future. Appendix C shows a cumulative summary of student course evaluations, including numerical ratings and sample written comments. Since this curriculum is still under development, these student responses have provided valuable feedback concerning course structure and LAP content.

Class Testing In Existing Chemistry Courses

A few selected LAPs have been used in existing 5-credit chemistry courses in the past year, by two other instructors. During 1996-97, appropriate LAPs will be more extensively incorporated into the curriculum of the one year sequence of General-Organic-Biochemistry course (Chem 161, 162,163) and the one-quarter liberal arts chemistry course (Chem 100) at SCC.

Peer reviews of the first three LAP modules (FC, NF and EV series) have been arranged through a publisher. These LAPs may also be made available for class testing in other institutions. I welcome questions or inquiries, and invite interested colleagues to class-test the curriculum in your institutions. For more information, please contact me at the postal address given in the beginning of this paper. You may also reach me by phone (509-533-8826) or by e-mail (rwang@ctc.edu).

Appendix A. List of LAP Titles

Fundamental Concepts Module:

- FC.1 - Atoms & Molecules
- FC.2 - Atomic Structure and Reactivity
- FC.3 - Chemical Bonding
- FC.4 - Water and Its Properties
- FC.5 - Chemical Reactions
- FC.6 - Acid Base and pH
- FC.7 - Redox Reactions
- FC.8 - Mole Concept
- FC.9 - Solutions
- FC.10 - Carbon Compounds

Nutrition & Food Module:

- NF.1 - Minerals
- NF.2 - Energy and Food
- NF.3 - Vitamins
- NF.4 - Fats & Oils
- NF.5 - Lipids
- NF.6 - Carbohydrates (1): Classification and Biological Functions
- NF.7 - Carbohydrates (2): Optical Activity
- NF.8 - Proteins (1): Amino Acids and Biological Functions
- NF.9 - Proteins (2): Native Structures and Denaturation
- NF.10 - Food Additives (a library and take-home study)

Environmental Chemistry Module:

- EV.1 - Our Physical Environment (1): The Atmosphere
- EV.2 - Our Physical Environment (2): The Hydrosphere and The Lithosphere
- EV.2.1 - Hardness of Water (a laboratory experiment)
- EV.3 - Water Treatment and Analysis: Chlorination
- EV.4 - The Air and Air Pollution
- EV.5 - Acidic Air Pollutants and Acid Rain
- EV.6 - Solid wastes
- EV.6.1 - Practical Uses for MSDS
- EV.7 - Hazardous Waste Management
- EV.8.1 - Ozone Depletion; 8.2 - Global Warming; 8.3 - Acid Rain (three library research projects)
- EV.9 - Analysis of Cigarette Smoke (a laboratory project)
- EV.10 - Chemical Analysis in Modern Laboratory (a field study project)
- EV.11 - Municipal Solid Wastes: Practical Studies (six small projects on issues of waste reduction, recycling and incineration.)

Nuclear Chemistry Module*: (This module is under development in 1996-7. All subjects are tentative.)

Atoms & Atomic Structure: Two sessions (4 hours)

- Nuclear atom and the three subatomic particles
- isotope symbols
- Alpha, beta and gamma radiation
- Methods for detecting radioactivity
- Experimental exercises include using radiation counter to study how different types of shielding affect alpha, beta, gamma sources.

Radioactivity & Half Life: One Sessions (2 hours)

- Exponential decay and half-life
- Carbon-14 and other types of dating based on radioactivity
- How half lives of radioactive materials relate to their usefulness and/or harmfulness.
- Experimental exercises include determining half life of Ba-137m.

Nuclear Energy: One session (2 hours)

- Different types of nuclear processes: transmutation, fission, fusion and natural decay
- Complete and balance nuclear equations
- Einstein's equation and mass-energy conversion
- Hands-on exercises include testing radioactivity of household products such as smoke detectors, mantle of camping lantern, watch dials, etc.; and a board game.

Nuclear Power and Nuclear Wastes: One sessions (2 hours)

- Nuclear fission reactor design
- Typical reactors in use today
- Current technology in waste treatment
- Problems and benefits of nuclear power generation
- Hands-on exercises may include field trip, library research and/or special presentations from interest groups.

Nuclear Medicine: One Sessions (2 hours)

- Principle and Types of isotopes used in diagnostic tests
- Radiation therapy
- Laboratory tests based on radioactivity
- hands-on exercises may include field trip to hospital labs or imaging centers, student reports on one particular aspect of the subject.

Medicine and Health Module: (This module will be developed in 1996-7.)

- ⇒ Over-The-Counter Drugs
- ⇒ Drug Analysis by Thin-Layer Chromatography
- ⇒ Nucleic Acid Chemistry
- ⇒ Genetic Engineering / Gene Therapy
- ⇒ etc.

APPENDIX B. Sample LAP Schedule for Chem 100 Survey of Chemistry, a 5-credit (quarter system) lab science course for liberal arts students at Spokane Community College. Class meets 7 hours per week, which include 3 LAP sessions (2 hours each) and 1 lecture session (1 hour). The course as scheduled emphasizes environmental chemistry with some nutrition and food chemistry. It can be easily scheduled otherwise to emphasize different modules, such as nuclear and medicine, etc.

Monday	Tuesday	Wednesday	Friday
			SEP 20 #1 Atoms & Molecules FC.1
SEP 23 #2 Atomic Structure FC.2	SEP 24 Lec discussion	SEP 25 #3 Classification of Matter (a supplementary lab)	SEP 27 #4 Chemical Bonding FC.3
SEP 30 #5 Water and Its Properties FC.4	OCT 1 Lec discussion	OCT 2 #6 Our Physical Environment EV.1	OCT 4 #7 Chemical Reactions FC.5
OCT 7 #8 Review Presentations	OCT 8 Quiz #1	OCT 9 #9 Acid-Base and pH FC.6	OCT 11 #10 Hydrosphere & Lithosphere EV.2
OCT 14 #11 Hardness of Water EV.2.1	OCT 15 Lec discussion	OCT 16 #12 Mole Concept FC.8	OCT 18 NO CLASS
OCT 21 #13 Solutions FC.9	OCT 22 Lec discussion	OCT 23 #14 Titration of Vinegar (a supplementary lab)	OCT 25 #15 Carbon Compds FC.10
OCT 28 #16 Review Presentations	OCT 29 Quiz #2	OCT 30 #17 Redox Reactions FC.7	NOV 1 #18 Analysis of Water EV.3
NOV 4 #19 The Air & Air Pollutants EV.4	NOV 5 Lec discussion	NOV 6 #20 Acidic Air Pollutants EV.5	NOV 8 #21 Solid Wastes EV.6
NOV 11 #22 Hazardous Waste Management EV.7	NOV 12 Lec discussion	NOV 13 #23 Practical Uses for MSDS EV.6.1	NOV 15 #24 To be announced
NOV 18 #25 Review Presentations	NOV 19 Quiz #3	NOV 20 #26 Minerals NF.1	NOV 22 #27 Energy & Food NF.2
NOV 25 #28 Vitamins NF.3	NOV 26 project prep	NOV 27 NO CLASS	NOV 29 NO CLASS
DEC 2 #29 Fats & oils NF.4	DEC 3 project prep	DEC 4 #30 Carbohydrates NF.6	DEC 6 #31 Research or Lab Project
DEC 9 #32 Proteins NF.8	DEC 10 Review Presentations	DEC 11 Review Presentations Quiz #4	

Appendix C. Summary of Student Evaluation from Chemistry Mini-Courses

Numerical Ratings: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, Poor = 1, N/A = 0

- **Mini-Course Structure:** Two-hour sessions = 4.34; Twice a week schedule = 4.3; Eight sessions per one credit = 4.03; Format of each session = 4.29; Use of class time = 4.29
- **Grading Policy:** Grading policy in general = 4.21; Requirement for Quizzes = 4.15; Amount of work involved for the credit received = 3.61
- **Curriculum:** Content Organization = 4.48; Hands-on learning activities = 4.41; Content level = 4.32; Interest level = 4.27; Helps me think through for myself = 4.25; Style of learning activities = 4.2; Usefulness of content = 4.24; Amount I learned = 4.27

Comparison between this course and other science courses:

- Is this course easier or harder: 57% easier, 27% the same, 16% harder
- Is this course more or less interesting? 77% more, 13% the same, 10% less.
- Did you learn more or less in this course? 77% more, 16% the same, 6% less
- Would you take more courses like this one? 82% yes, 6% maybe, 12% no

Comments: (Students were asked to complete three sentences concerning the course.)

The best thing about this course is...

45% of the comments relate to **pedagogy**. sample comments:

- The hands on experiments (learn by doing)
- the diversity of each weeks lesson
- It is presented in a manner that makes chemistry interesting & easy to learn

23% of the comments relate to **the instructor**. Sample comments are:

- Dr. Wang is an instructor that encouraged me to do more than what I think I can.
- Teacher is very helpful, wants the students to learn.

20% of the comments relate to **relevance of course content**. Sample comments are:

- the way the concepts was presented was easy to understand. I especially like the way the science lessons could be applied or observed in everyday life.
- Concepts were described in a way that could be related to real life.

12% of the comments relate to the **"mini-" aspect of the course**. Sample comments are:

- Part Time
- flexibility fits into schedule of other classes

The worst thing about this course is...

49% of the comments mention **amount of work involved**. Sample comments are:

- the labs were great but maybe a little pressed for time
- size of some packets

38% of the comments are

class schedule and grading policy. Sample comments are:

- If you miss a day you grade can drop & lots of missed labs & homework
- having the course meet on consecutive days

Advice to other students taking this course...

72% of the comments stress the importance of class time and the LAPs. Examples:

- Read material closely and make sure concepts are understood. If no help is available during class time seek help outside class time.
- Study packets carefully, lots of information
- Do not miss a day or you will be behind. Read the activity packets from front page to last.
- Have fun, it makes learning easier, take the time to read and go over review questions even when you don't have to present. They help.

18% of the comments simply recommend the course. Sample comments are:

- It's a good course before taking any other science classes.
- Excellent quick & easy course for people who want to learn chemistry
- Very good to get your "feet wet" with!
- Very good course, if you want to learn about your nutrition & health.

10% of the comments mention the mind-set for class sessions. Sample comments are:

- better come prepared to think
- Be prepared to study a lot. Think!